Southern California Priority Corridor
Showcase Program Evaluation

IMAJINE Evaluation Report

FINAL
VERSION 1

March 17, 2003

Document No. 65A0030/0029
Task No. 5-12

Prepared for
California Department of Transportation
Division of Research & Innovation, MS-83
1227 O Street
Post Office Box 942873
Sacramento, California 94273-0001

Prepared By
BOOZ ALLEN HAMILTON INC
1615 Murray Canyon Road, Suite 220
San Diego, California 92108

CONTENTS

Disclaimer

The contents of this report reflect the views of the author who is responsible for the facts and accuracy of the data presented herein. The contents do not necessarily reflect the official views or policies of the State of California, Caltrans or the U.S. Federal Highway Administration. This report does not constitute a standard, specification, or regulation.

Abbreviations & Acronyms

ATIS	Advanced Traveler Information System
ATMS	Advanced Transportation Management System
AVL	Automatic Vehicle Location
Caltrans	California Department of Transportation
CCTV	Closed-circuit Television surveillance camera
CM	Configuration Management
CMP	Configuration Management Plan
CMS	Changeable Message Sign
CORBA	Common Object Request Broker Architecture
COTS	Commercial Off-the-Shelf
CTC	California Transportation Commission
CVO	Commercial Vehicle Operations
CW	Corridor-wide
CWATIS	Corridor-wide Advanced Traveler Information System Project
CWATMS	Corridor-wide Advanced Transportation Management System Project
CWCVO	Corridor-wide Commercial Vehicle Operations Project
CWSIP	Corridor-wide Systems Integration Project
CWSPP	Corridor-wide Strategic Planning Project
DOIT	Department of Information Technology
DRI	Caltrans Division of Research & Innovation (formerly NTR)
EAP	Evaluation Activity Plan
EP	Evaluation Plan
FHWA	Federal Highway Administration
FSR	Feasibility Study Report
FTA	Federal Transit Administration
FTE	Full-Time Equivalent (one full-time employee)
GPRA	Government Performance and Results Act
GUI	Graphical User Interface
HP	Hewlett-Packard
HQIT	Headquarters - Information Technology (division of Caltrans)
IDL	Interface Definition Language
IPR	Intellectual Property Rights
ITS	Intelligent Transportation Systems
ISSC	Information Systems Service Center (division of Caltrans)
ISTEA	Intermodal Surface Transportation Efficiency Act (of 1991)
LACDPW	Los Angeles County Department of Public Works
LADOT	City of Los Angeles Department of Transportation
LAN	Local Area Network
MOU	Memorandum of Understanding
MPO	Metropolitan Planning Organization
MTA	Los Angeles County Metropolitan Transportation Authority
MTBF	Mean Time Between Failure
NDA	Non-Disclosure Agreement

NET	National Engineering Technology Corporation
NTCIP	National Transportation Communications for ITS Protocol
NTR	Caltrans Division of New Technology & Research
OCTA	Orange County Transportation Authority
O&M	Operations and Maintenance
OS	Operating system (such as Windows™, Unix, Linux, et. al.)
PC	Personal Computer (Windows™-based)
RCTC	Riverside County Transportation Commission
RFP	Request for Proposals
RTP	Regional Transportation Plan
RTPA	Regional Transportation Planning Agency
RWS	Remote Workstation
SANBAG	San Bernardino Association of Governments
SANDAG	San Diego Association of Governments
SCAG	Southern California Association of Governments
SCAQMD	South Coast Air Quality Management District
SCPCSC	Southern California Priority Corridor Steering Committee
SIP	Systems Integration Plan
TEA-21	Transportation Equity Act for the 21st Century
TMC	Transportation Management Center
USDOT	United States Department of Transportation
VDS	Vehicle Detector Station
VOS	Volume/Occupancy/Speed
VCTC	Ventura County Transportation Commission
WAN	Wide Area Network

Executive Summary

Background

As required by federal law, all Intelligent Transportation System (ITS) projects that receive federal funding must undergo an evaluation to help assess the costs and benefits of ITS. This document is one of 23 reports produced as part of the Southern California ITS Priority Corridor Showcase Program Evaluation to help planners and decision-makers at the federal, state and local levels make better-informed decisions regarding future ITS deployments. This report presents the experiences, costs, and lessons learned from Southern California's IMAJINE project.

In 1993, the U.S. Department of Transportation designated Southern California as one of four Priority Corridors in which ITS could have particular benefit. Southern California suffers from extreme traffic congestion, limited room for expanding transportation facilities, and above-average air pollution levels. The Southern California Priority Corridor is one of the most populated, traveled, and visited regions in the country, and consists of four adjoining regions:

- Los Angeles/Ventura
- Orange County
- San Diego County
- Inland Empire (San Bernardino and Riverside Counties).

The ITS Showcase Program is one of several programs that have been implemented in Southern California's Priority Corridor to help aid mobility and mitigate traffic congestion and its associated environmental impacts. The Showcase Program consists of 17 ITS projects that collectively form a corridor-wide intermodal transportation management and information network between Los Angeles, Orange County, San Diego, and the Inland Empire. Each Showcase project deploys a piece of this corridor-wide ITS network, including regional Advanced Traveler Information Systems (ATIS), regional Advanced Transportation Management Systems (ATMS), and regional and interregional communications infrastructure. Eleven of the projects are regional in nature, while the remaining six are corridor-wide. IMAJINE is one of the eleven regional projects within the Southern California Priority Corridor ITS Showcase Program.

IMAJINE is an acronym for Inter-Modal and Jurisdictional Integrated Network Environment. The system enables operators and systems at Access Services Inc. (ASI), Caltrans District 7, Los Angeles County Metropolitan Transportation Authority (MTA), and the City of South Gate exchange information for better-coordinated service.

The IMAJINE system was designed to provide a particular benefit to each project partner. As the local fixed-route transit provider, MTA provides up-to-date transit routes, schedules, and fare information. ASI, the region's contracted paratransit service

provider, uses MTA's information to coordinate service and prepare transit itineraries for patrons over the phone. Caltrans District 7 provides information regarding highway events, including freeway condition data, camera images, and current CMS messages. South Gate uses the highway incident information from Caltrans District 7 to automatically execute response plans that adjust traffic signal timings along major arterial feeder and diversion routes. In the future, the system might also be used to provide traffic signal priority to MTA buses equipped with automatic vehicle location (AVL) technology.

Evaluation Findings, Conclusions, and Recommendations

IMAJINE brings the Los Angeles region one step closer to achieving its vision of integrated ITS by helping to lay both a physical and institutional foundation for further ITS development and expanded exchange and use of transportation information among the regional partners. IMAJINE is the first system to be fully compliant with the Priority Corridor's Showcase Architecture, and it is the first Showcase project to successfully integrate local transportation management centers with the interregional Showcase Network.

IMAJINE's goal was to build an architecture and capability to integrate and exchange real-time transportation information. This capability has been successfully provided and proven through sample data transfers between systems at MTA, Caltrans District 7, South Gate and ASI. However, IMAJINE is only the first step of a multi-stage regional effort, and the transportation system impacts of the system are expected to become much greater as additional equipment is installed. IMAJINE's functionality will be enhanced by the procurement, installation and integration of additional equipment such as transit bus AVL and alternative traffic signal timing plans. The MTA is currently seeking funding to procure the transit AVL system, and development of the alternative traffic signal timing plans is planned as part of the currently ongoing I-105 Corridor/Gateway Cities project.

The fixed-price IMAJINE contract initially specified an 18-month period of performance due to FHWA requirements, but various factors contributed to exceeding this schedule:

- IMAJINE was developed concurrently and interdependently with two other projects: Showcase's Scoping & Design project (which developed the Showcase Kernel and critical interface standards for the entire Priority Corridor), and LACDPW's I-105 Corridor/Gateway Cities Subregional TMC project. Delays with both of these projects impacted IMAJINE.

- Consensus building takes time. Although IMAJINE's software implementation, integration and testing was able to be done in about 18 months, the coordination, consensus building and system planning that preceded these activities required nearly three years of effort. Although IMAJINE provides a data exchange capability between four agencies, additional stakeholder agencies involved in the planning

process included FHWA, SCAG, LACDPW, Caltrans Division of New Technology & Research (now the Division of Research & Innovation), and the City of Los Angeles. This planning and consensus building took place in steps as project deliverables were released to the stakeholder group.

The two deliverables that required the most time were the User Requirements and Systems Requirements documents. Each of these documents required about six months of consensus building, preparation, review, discussion, and revision to complete. Future ITS projects might benefit from the following observations regarding system planning and document development:

1. Approach the system development in "baby steps." Keep the first implementation as simple as possible by focusing on only the most basic and critical system requirements, and leave less critical items to future builds of the system. During the IMAJINE project, workshops were held to capture stakeholders' desires for the system. All of these desires were catalogued in the project's Requirements document, but an additional Implementation Phasing Plan (IPP) was developed to specify which requirements would be implemented immediately and which ones would be saved for future builds. This approach encouraged stakeholders to be open and creative, provided an archive for the ideas generated, but also provided a mechanism for managing what could be reasonably accomplished within the existing project budget.

2. Develop and use formal document review procedures that define the manner and format in which comments/issues will be received, processed, and resolved. With so many stakeholders involved in the IMAJINE project, this helped streamline the task considerably.

3. If schedule adherence is a top priority for the project, strictly limit the amount of time to read and review a document to two weeks, and gain stakeholder commitment to maintain this schedule. Although this will help keep the project on schedule, it may conflict with stakeholders' busy schedules and hinder or sacrifice their involvement. The IMAJINE project team considered stakeholder involvement to be a higher priority, so document reviews were sometimes extended to several months.

4. Make formal oral presentations of major documents to stakeholders in order to gather direct feedback and respond more quickly to stakeholder concerns. This is particularly useful for large, detailed documents that would otherwise require a more careful and lengthy review. This approach provides an opportunity to discuss any overly detailed information, as well as helps summarize and bring focus to the more important items that may require timely stakeholder action. The project team used this approach to present the system's Detailed Design document.

5. Dictate drafts of major documents onto tape or CD and circulate them as "books-on-tape" so that they are more convenient to carry and review while traveling, commuting, etc. This may be useful for those who are looking for ways to more efficiently use their time. Although this approach was not employed during the IMAJINE project, the evaluation provides it as a novel approach for others to consider.

Regardless of the extra time required to complete the IMAJINE project, the project was completed within its initial budget. This adherence to the original budget is due in part to cost-mitigating actions, such as occasional work stoppages, taken by the project team. Future ITS projects might benefit from a phased or task order approach that permits a re-evaluation of the project's progress and costs after each systems engineering step. This approach would aid in estimating project cost and duration, and would relieve some of the financial risk imposed on contractors by fixed-price agreements.

Since operations and maintenance of the system is funded by each respective partner agency, low O&M costs were an important design consideration. This requirement has been met with an estimated annual O&M cost per agency, including power and telecommunications services, of between $1932 and $2651 (or about $200 per month). Since agency staff resources are often limited, much of the IMAJINE system is designed to operate autonomously, thus avoiding additional labor costs.

1 Introduction

1.1 Purpose and Scope of this Report

As required by federal law[1], all Intelligent Transportation System (ITS) projects that receive federal funding must undergo an evaluation to help assess the costs and benefits of ITS. The information provided in this report is intended to help planners and decision-makers at the federal, state and local levels make better-informed decisions regarding future ITS deployments based on the experiences of Southern California's IMAJINE project.

This document is one of 23 reports produced as part of the Southern California ITS Priority Corridor Showcase Program Evaluation, and covers only the events and findings resulting from the IMAJINE evaluation. The complete set of findings from the Showcase Program Evaluation are found in the following collection of documents:

Document Type/Title	Date	Document Number
17 Individual Project Evaluation Reports		
Corridor-wide ATIS Project Report	TBD	
Corridor-wide ATMS Project Report	TBD	
Corridor-wide CVO Project Report	TBD	
Corridor-wide Rideshare Project Report	TBD	
Corridor-wide Strategic Planning Project Report	10/29/2002	65A0030/0028
Fontana-Ontario ATMIS Project Report	TBD	
IMAJINE Project Report	**3/17/2003**	**65A0030/0029**
IMTMC Project Report	TBD	
InterCAD Project Report	TBD	
Kernel Project Report	TBD	
LA ATIS Project Report	TBD	
Mission Valley ATMIS Project Report	TBD	
Mode Shift Project Report	TBD	
OCMDI Project Report	TBD	
Traffic Signal Integration Project Report	TBD	
Transit Mgt System Project Report	TBD	
TravelTIP Project Report	TBD	
5 Cross-Cutting Evaluation Reports		
System Performance Cross-Cutting Report	TBD	
Costs Cross-Cutting Report	TBD	
Institutional Issues Cross-Cutting Report	TBD	
Information Management Cross-Cutting Report	TBD	
Transportation System Impacts Cross-Cutting Report	TBD	
Final Summary Evaluation Report		
Showcase Program Evaluation Summary Report	TBD	

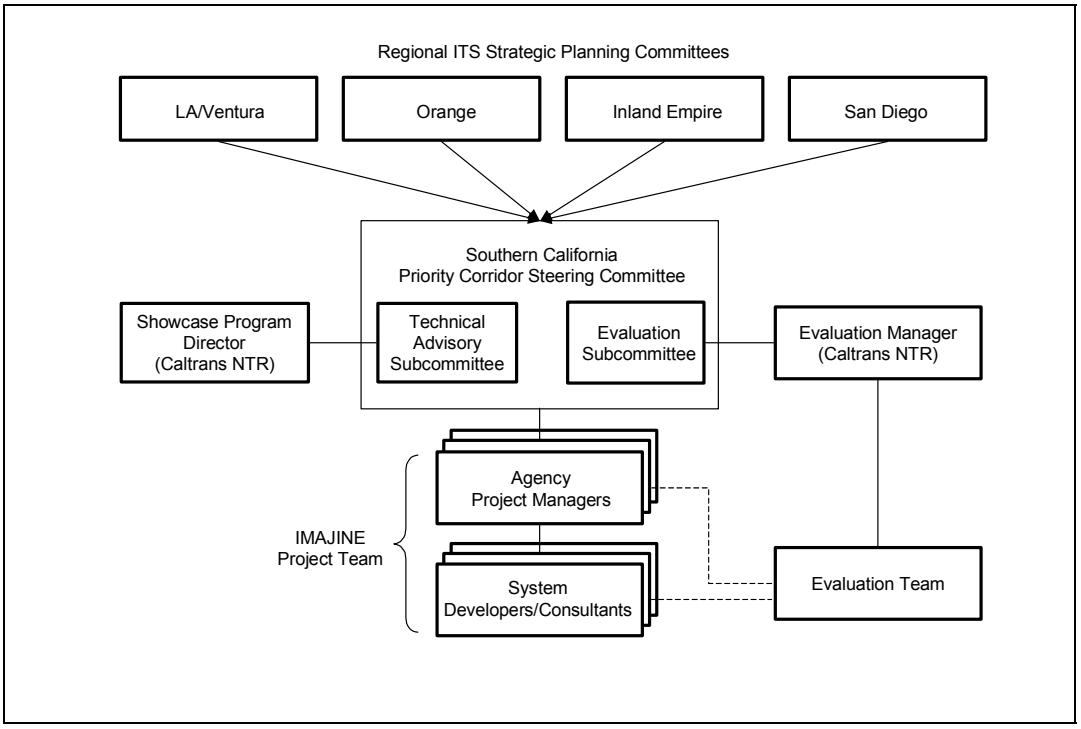
"TBD" indicates a future deliverable that is not yet available.

1.2 Evaluation Design and Approach

The findings outlined in this report are based on over four years of direct observations at project meetings, reviews of released project documents and agency memos, as well as formal and informal interviews and discussions with project partners.

The evaluation is responsive to the needs and suggestions of the Priority Corridor's Evaluation Subcommittee, which reports to the Priority Corridor's Steering Committee. As shown in Exhibit 1, both committees are comprised of stakeholders from the federal, state, and local levels.

Exhibit 1 – Management Structure and Organization of the Showcase Program



The Steering Committee's member agencies reflect wide representation from the region in terms of federal and state highway agencies, public safety, cities and counties, transit, air quality and regional planning entities, including:

- California Highway Patrol (CHP)
- Caltrans, Division of Research and Innovation (DRI) (formerly the Division of New Technology & Research (NTR))*
- Caltrans, District 7*
- Caltrans, District 8*
- Caltrans, District 11*
- Caltrans, District 12
- City of Irvine*
- City of Los Angeles Department of Transportation (LADOT)

- City of San Diego
- Federal Highway Administration (FHWA)*
- Federal Transit Administration (FTA)
- Los Angeles County Metropolitan Transportation Authority (MTA)
- Orange County Transportation Authority (OCTA)
- Riverside County Transportation Commission (RCTC)
- San Bernardino Association of Governments (SANBAG)
- San Diego Association of Governments (SANDAG)
- South Coast Air Quality Management District (SCAQMD)
- Southern California Association of Governments (SCAG).

* Indicates an Evaluation Subcommittee member

The Showcase Program's Evaluation Design is based on a set of evaluation Goals and supporting Objectives and Measures that were developed by the Evaluation Team in partnership with federal, state and local stakeholders, and documented in the "Showcase Program Evaluation Approach" in 1998. Each individual Showcase project is evaluated based on an applicable subset of these Goals, Objectives, and Measures in order to help ensure that summary evaluation results can be aggregated from across the multiple Showcase project evaluations. The Showcase Program's five evaluation Goals include:

- Evaluate System Performance
- Evaluate Costs
- Evaluate Institutional Issues and Impacts
- Evaluate the Use and Management of Transportation/Traveler Information
- Evaluate Transportation System Impacts.

As IMAJINE evolved, project-specific refinements to the evaluation design were documented in a high-level Evaluation Plan (EP) and a detailed Evaluation Activity Plan (EAP). In general, the EP describes the project and/or system under evaluation, and lays the foundation for further evaluation activities by developing consensus among the Evaluation Subcommittee and project partners as to which of Showcase's evaluation Goals, Objectives, and Measures best apply to the project.

As the project matured, and after the EP had been approved, an EAP was developed to plan, schedule, and describe specific activities (e.g., interviews, surveys) and step-by-step procedures for conducting the evaluation. Data collection began after both plans had been reviewed and subsequently approved by the Evaluation Subcommittee and the project's partners.

1.3 Organization of this Report

The IMAJINE Evaluation Report provides a background description of the Southern California Priority Corridor and the transportation challenges facing Los Angeles County. This is followed by descriptions of the Showcase Program and the IMAJINE project, including a detailed technical description. The evaluation itself is subdivided and ordered into the five topic areas described below:

System Performance — provides important benchmark information regarding system availability, reliability, scalability and compatibility. The evaluation quantifies those items and could be used to identify needed improvements and help develop specifications for future systems.

Cost — provides important benchmark information regarding funding sources, software licensing, development costs, costs to re-deploy elsewhere or expand the system, and operations and maintenance (O&M) costs. This report includes an estimate of how much it might cost to re-deploy IMAJINE "from scratch" elsewhere in the State, and also looks at the incremental costs for integrating additional partner agencies and/or traveler information kiosks into the existing system.

Institutional Impacts — provides important information regarding the administrative, procedural and legal impacts resulting from the deployment of IMAJINE. Such impacts include changes in operator workloads, responsibilities and job turnover rates, as well as changes and limitations of agency-wide policies, procedures and guidelines.

Transportation & Traveler Information Management — provides important benchmark information on system usage and user acceptance (by both agency operators and the general public). This report provides both quantitative and qualitative findings on those items and can be used to identify user demand, needed improvements and potential areas of future growth.

Transportation System Impacts — provides important information regarding IMAJINE's impacts on transit usage, traffic congestion, air quality, and traffic safety.

The report concludes with a summary, final remarks and recommendations for next steps. Several appendices contain supporting documentation such as technical designs and copies of evaluation data collection instruments (blank questionnaires and survey).

1.4 Privacy Considerations

Some of the information acquired in the interview and discussion process could be considered sensitive and has been characterized in this report without attribution. The Evaluation Team has taken precautions to safeguard responses and maintain their confidentiality. Wherever possible, interview responses have been aggregated during analysis such that individual responses have become part of a larger aggregate response. The names of individuals and directly attributable

quotes have not been used in this document unless the person has reviewed and expressly consented to its use.

1.5 Constraints & Assumptions

The IMAJINE evaluation is subject to the following constraints and assumptions:

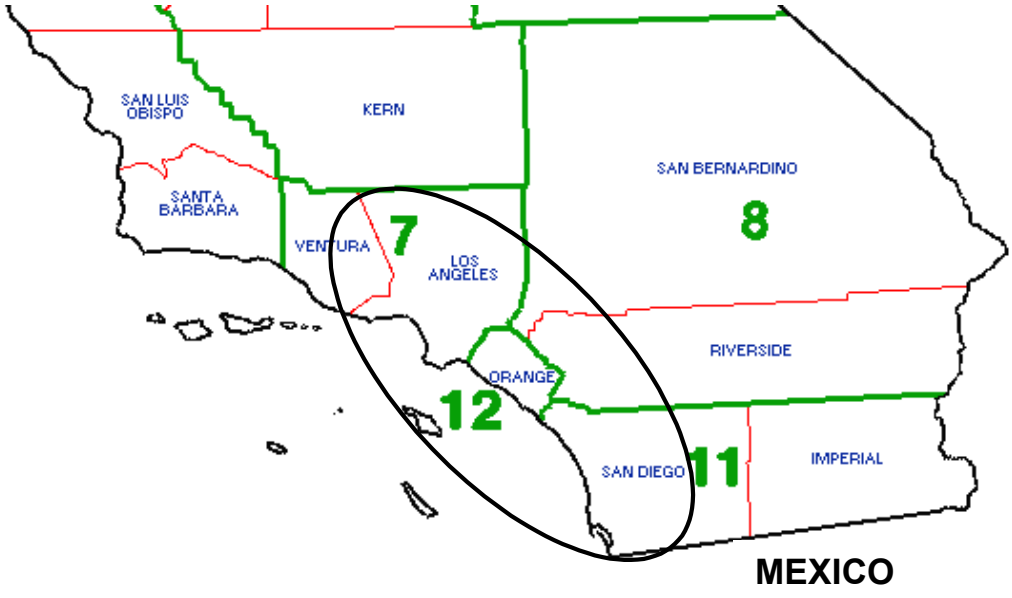
- The project's consultant was not required to disclose actual project expenses, so the project's cost is based on the fixed-price budget stipulated in the IMAJINE contract and its amendments. The budget reflects the expenses and costs for services paid by the client agency, but not necessarily the actual detailed costs for goods and services comprising the project.

1.6 Project Background

1.6.1 The Southern California Priority Corridor

In 1993, the U.S. Department of Transportation designated Southern California as one of four Priority Corridors in which Intelligent Transportation Systems (ITS) could have particular benefit. Southern California suffers from extreme traffic congestion, limited room for expanding transportation facilities, and above-average air pollution levels. The Southern California Priority Corridor, illustrated in Exhibit 2, is one of the most populated, traveled, and visited regions in the country.

Exhibit 2 – The Southern California Priority Corridor and Vicinity



The Southern California Priority Corridor consists of four distinct regions that correspond with the four Southern California Caltrans districts:

- Los Angeles/Ventura (Caltrans District 7)
- Orange County (Caltrans District 12)
- San Diego County (Caltrans District 11)
- Inland Empire (Caltrans District 8).

Roughly two-thirds of the state's population – about 20 million people – resides in or around the Southern California Priority Corridor.

Exhibit 3 – Population and Number of Registered Vehicles by County

County	Population[2] (as of 7/1/2001)	Registered Vehicles[3]* (as of 12/31/2000)	Caltrans District
Los Angeles	9.7 million	6.2 million	7
Orange	2.9 million	2.1 million	12
San Diego	2.9 million	2.1 million	11
San Bernardino	1.8 million	1.1 million	8
Riverside	1.6 million	1.1 million	8
Ventura	0.8 million	0.6 million	7
Imperial	0.15 million	0.1 million	11
Total	**19.85 million**	**12.7 million**	

*Includes autos, trucks, and motorcycles. Trailers not included.

1.6.2 The Southern California Priority Corridor's ITS Showcase Program

The ITS Showcase Program is one of several programs that have been implemented in Southern California's Priority Corridor to help aid mobility and mitigate traffic congestion and its associated environmental impacts.

The Southern California ITS Showcase Program consists of 17 individual ITS projects that collectively form a corridor-wide intermodal transportation management and information network between Los Angeles, Orange County, San Diego, and the Inland Empire. Eleven of the projects are regional in nature, while the remaining six are corridor-wide in scope. Los Angeles County's IMAJINE project is one of the eleven regional projects.

The 17 Showcase projects are listed by region in Exhibit 4. Eight of the projects, including IMAJINE, were fast-tracked and designated "Early Start" projects because of their importance as base infrastructure and potential to act as role models for the rest of the Showcase Program.

Exhibit 4 – The 17 Showcase Projects and their Status as of January 2003

Project	RFP Issued	Contractor Selected	Contract Executed	Project Underway	Project Complete
Corridor-wide					
Scoping & High Level Design (Kernel)*	✓	✓	✓	✓	✓
Strategic Planning/Systems Integration	✓	✓	✓	✓	✓
CVO🗎					
ATIS	✓	✓	✓	✓	✓
ATMS🗎					
Rideshare	✓	✓	✓	✓	✓
Los Angeles Region					
IMAJINE*	✓	✓	✓	✓	✓
Mode Shift*	✓	✓	✓	✓	
LA ATIS	✓	✓	✓	✓	
Inland Empire Region					
Fontana-Ontario ATMIS	✓	✓	✓	✓	
Orange County Region					
TravelTIP*	✓	✓	✓	✓	✓
OCMDI	✓	✓	✓	✓	✓
San Diego Region					
InterCAD*	✓	✓	✓	✓	✓
Mission Valley ATMIS*	✓	✓	✓	✓	
IMTMS/C (ATMSi)*	✓	✓	✓	✓	
Traffic Signal Integration (RAMS)	✓	✓	✓	✓	
Transit Management System*	✓	✓	✓	✓	

* Indicates an "Early Start" project.
🗎 CWCVO and CWATMS do not yet have approved workplans.

2 Project/System Technical Description

IMAJINE is an acronym for Inter-Modal and Jurisdictional Integrated Network Environment. The system enables operators and systems at Access Services Inc. (ASI), Caltrans District 7, Los Angeles County Metropolitan Transportation Authority (MTA), and the City of South Gate (as a proxy for the Gateway Cities Subregional TMC to be built by LACDPW in southeast Los Angeles County) to exchange information for better-coordinated service.

Each partner agency derives a particular benefit from the IMAJINE system. As the local fixed-route transit provider, MTA provides up-to-date transit routes, schedules, and fare information. ASI, the region's largest demand-response paratransit service provider, uses MTA's information to coordinate service and prepare transit itineraries for patrons over the phone. Caltrans District 7 provides information regarding highway events, including freeway condition data, camera images, and current CMS messages. South Gate uses highway incident information from Caltrans District 7 to automatically execute response plans that adjust traffic signal timings along major arterial feeder and diversion routes. In the future, the system might also be used to provide traffic signal priority to MTA buses equipped with automatic vehicle location (AVL) technology. The information exchanges are summarized in Exhibit 5, and described in more detail in Appendix A.

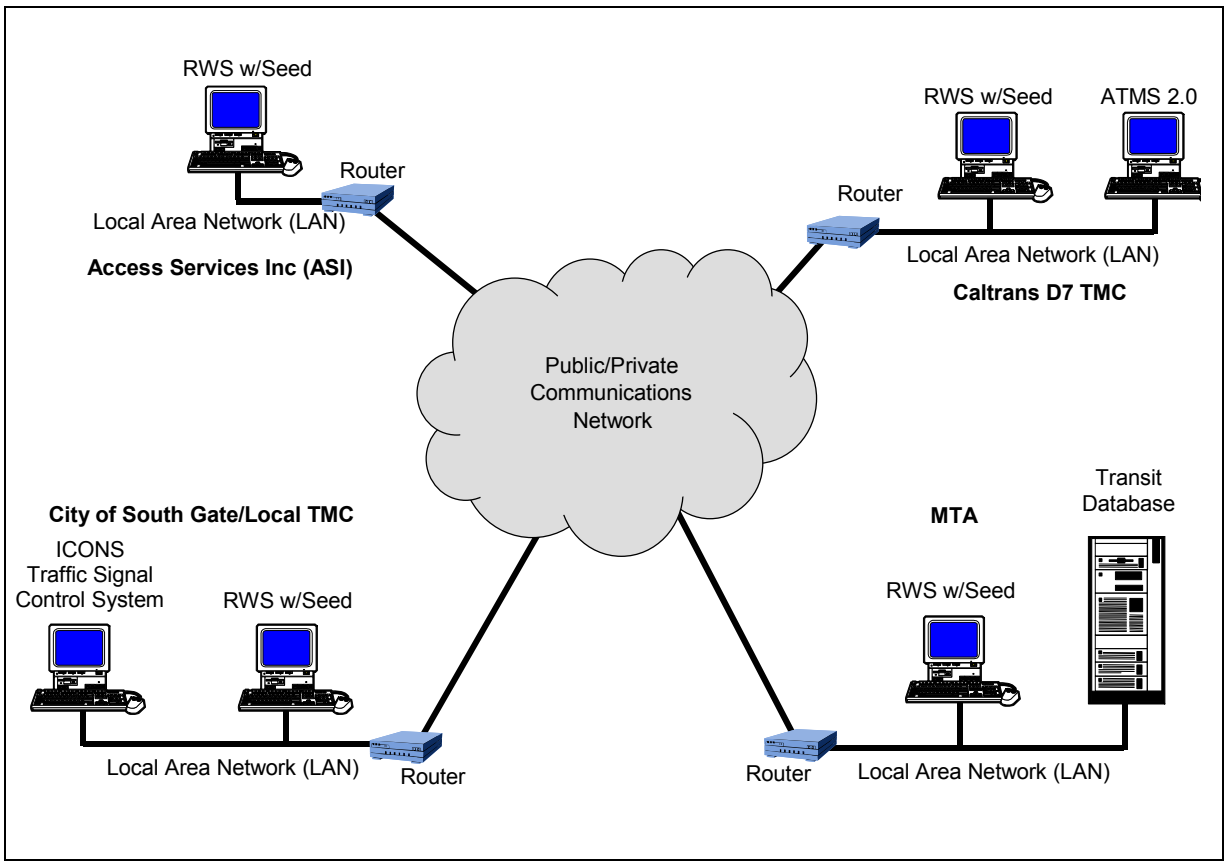
Exhibit 5 – IMAJINE Partners and Information Sharing Matrix

		To			
		ASI	**Caltrans D7**	**MTA**	**South Gate**
From	**ASI** • Does not provide any data		NA	NA	NA
	Caltrans D7 • Events/ Incidents (automated) • Real-time VOS data • CCTV (View only) • CMS (View only)	Data available for use.		Data available for use.	Hwy event data from Caltrans D7 is used to automatically execute pre-programmed response plans that adjust signal timings on a major city arterial.
	MTA • Up-to-date transit routes • Up-to-date transit timetables • Fare Information	ASI call-desk operators can use the information to advise patrons of transfer points, alternate routes, etc.	Data available for use.		Data available for use.
	South Gate • Advisories (entered manually) • Real-time VOS data	Data available for use.	Data available for use.	Data available for use.	

IMAJINE's partner agencies represent a diverse cross-section in terms of ITS experience and the amount of ITS infrastructure they had in place prior to IMAJINE. Caltrans District 7 and the MTA have been active in ITS for many years and had various legacy ITS systems in place. ASI and South Gate had no ITS in place prior to IMAJINE. The project successfully demonstrated the feasibility of integrating these diverse partners.

Exhibit 6 provides a high-level overview of the IMAJINE system design. Custom software designed and developed by IMAJINE is installed at each agency to extract the desired data from existing legacy systems. This custom software is tailored to the particular legacy system with which it interfaces, and is referred to in Showcase jargon as a "Seed." The Seed software resides on Remote Workstations (RWS) that also provide a Windows™-like graphical user interface (GUI) for allowing operators to adjust settings and view the available transportation information.

Exhibit 6 - IMAJINE High-Level System Design



IMAJINE is the first step in a much larger, multi-stage regional ITS effort that involves several planned and currently ongoing projects, including:

- Regional Integration of ITS (RIITS) project – This ongoing project by the MTA develops an ITS network for the Los Angeles/Ventura region, as well as helps institutionalize associated administrative functions such as configuration management. RIITS binds all of the region's other ITS projects together.

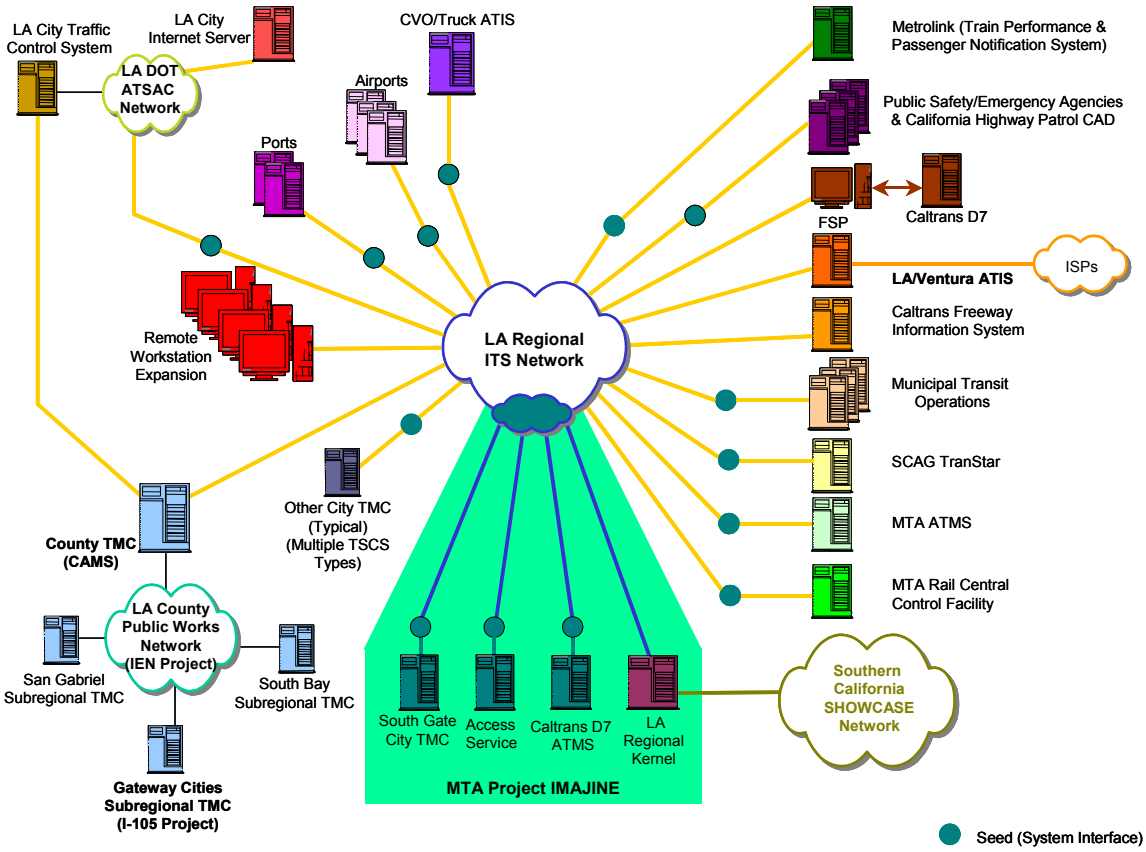
- Information Exchange Network (IEN) project – This ongoing project by the LACDPW integrates and coordinates the traffic signal systems of various cities throughout Los Angeles County. Once completed, the IEN will become a significant source of data regarding arterial traffic conditions throughout the county.

- Los Angeles/Ventura Regional ATIS (LA/Ventura ATIS) – This fellow Priority Corridor Showcase project is managed by the MTA and is close to completion. It revises and upgrades the IMAJINE software and hardware by utilizing the latest technology, adding features and functionality, and integrating additional agency partners onto the regional network. The additional partners/centers include LADOT's ATSAC, SCAG's TranStar database and LACDPW's IEN.

- Mode Shift project – This ongoing Priority Corridor Showcase project is managed by Caltrans District 7 and should be complete within the next 6-9 months. Mode Shift develops a website that helps travelers plan their trips. Users enter an origin, destination and other travel information, and the system calculates the best routes via both personal automobile and public transit. The goal is to show users that transit is sometimes a better mode of travel.

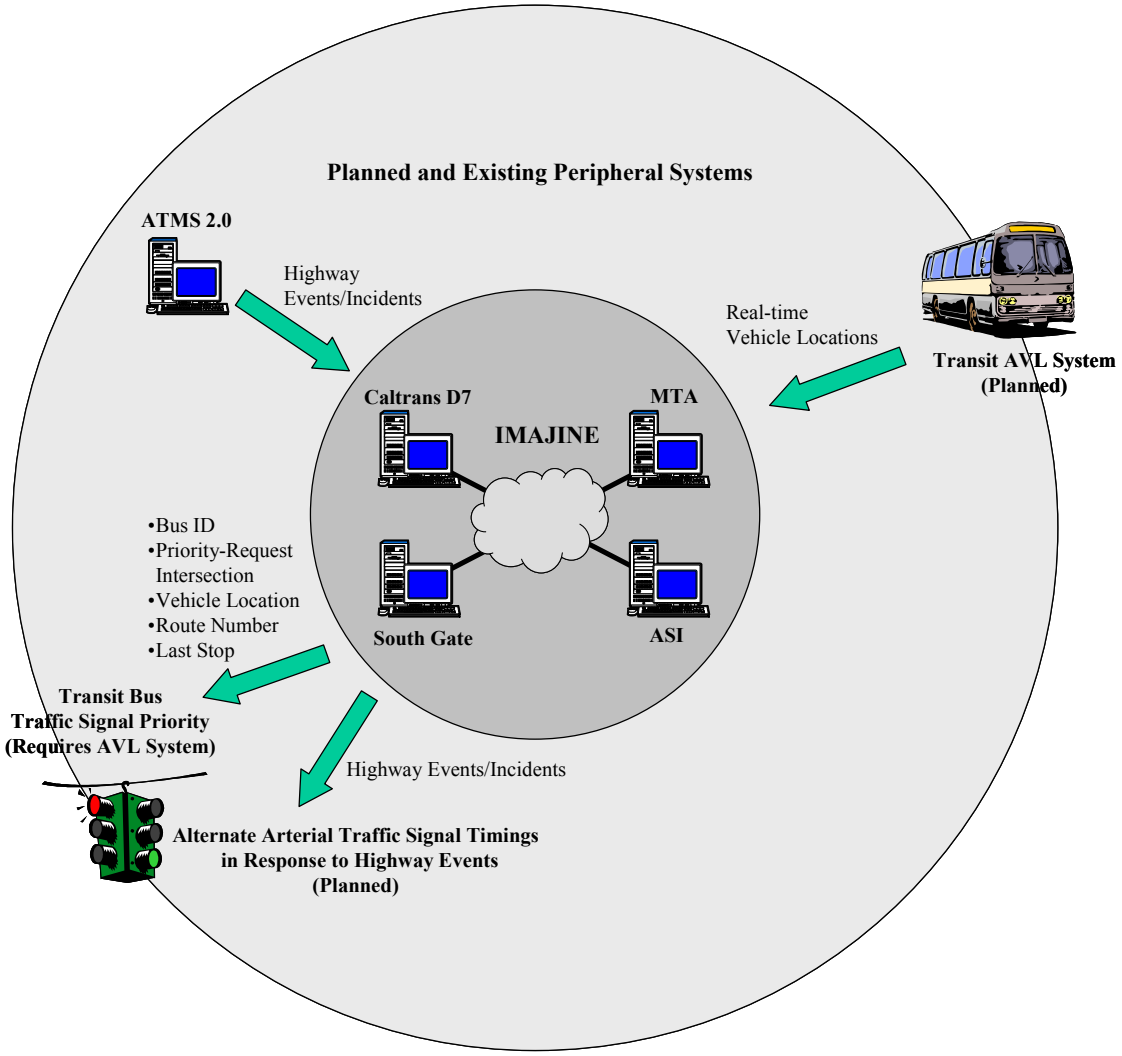
These projects, along with others, are shown as part of the MTA's Long Range ITS Master Plan in Exhibit 7.

Exhibit 7 – Systems to be Connected by the Los Angeles Regional ITS Network



IMAJINE provides the first installment of the region's integrated ITS network, and acts as a mediator to pass data between peripheral systems at the partner agencies. The full functionality of IMAJINE is currently awaiting the installation of these additional peripheral systems, such as the MTA's transit bus AVL system and South Gate's incident response traffic signal timing plans.

Exhibit 8 – IMAJINE Leverages Several Planned and Existing Peripheral ITS Systems



3 System Performance Evaluation

3.1 The Project/System Development Process and Timeline

IMAJINE's development followed a systems engineering process, but took much longer than originally anticipated.

IMAJINE is the culmination of roughly five years of effort. An initial RFP was issued in August 1996, but was later revised due to changes in the Scope of Work. A revised workplan was approved in November 1996, and the consultant (National Engineering Technology or NET) was selected in early (March-May) 1997. The contract was executed in June 1997 and the kick-off meeting was held on June 23. The project was successfully completed in October 2001.

IMAJINE is primarily a software development and systems integration project, and utilized the traditional systems engineering approach as evidenced by the following project milestones and deliverables:

- September 1997 – Needs Assessment completed.
- October 1997 – Inventory of Existing Systems completed.
- January 1998 – Concept of Operations completed.
- June 1998 – User Requirements completed.
- January 1999 – System Requirements completed.
- October 1999 – User Interface Working Paper completed.
- October 1999 – System Architecture Report completed.
- March 2000 – High Level Design completed.
- March 2000 – Implementation Phasing Plan completed.
- June 2000 – Detailed Design completed, including Detailed Software Design and Detailed Hardware and Communications Design.
- June 2001 – Integration with Kernel v0.3 completed.
- October 2001 – Integration with Kernel v1.0 completed.

The fixed-price IMAJINE contract initially specified an 18-month period of performance based on FHWA requirements, but as the dates on the above milestones reveal, the significant amount of time required to plan, design and reach consensus on Intelligent Transportation Systems was much longer. The above timeline shows that although software implementation, integration and testing was accomplished in slightly less than 18 months, the coordination, consensus building and system planning that preceded these activities required nearly three years of effort. This additional time required the contract to be amended to extend its period of performance; however, the project stayed within its original fixed-price budget.

3.2 System reliability, availability, compatibility, and scalability

3.2.1 System Reliability and Availability

In the system's roughly 12 months of operation, there has been no evidence of any system failures.

At this time, much of the functionality of the system is pending the future installation and integration of additional equipment. IMAJINE has the capability to process transit bus AVL data in order to provide traffic signal priority along certain arterials, but this feature is awaiting the installation of the AVL system (the MTA is currently seeking funding to procure this equipment). Likewise, IMAJINE enables the communication of freeway incident data from Caltrans District 7 to the City of South Gate for triggering alternative arterial traffic signal timing plans, which will be developed as part of the currently ongoing I-105 Corridor/Gateway Cities project. However, while some system features are awaiting the future installation and integration of additional equipment to be fully utilized, the system has been successfully tested and demonstrated on several occassions and performed well each time.

3.2.2 Compatibility

There are no indications of any system incompatibilities.

Compatibility is the ability of two or more systems or components to perform their required functions while sharing the same hardware or software environment. There have not been any system failures or anomalies experienced during the 12 months of this study that would indicate an incompatibility with the existing software/hardware environment.

3.2.3 Scalability

As a distributed, object-oriented system, IMAJINE is scalable to accommodate several additional centers.

Scalability describes the extent to which system usage can grow without sacrificing system performance or requiring architectural or technology changes. In this study, system usage is defined in terms of data (object) throughput and is measured in units of megabytes per second (MB/sec). System usage could increase due to an increased utilization of existing workstations or because of the addition of new centers and workstations onto the IMAJINE network. The factors that influence the system's scalability include:

- Hardware capability
- Software design.

IMAJINE primarily utilizes Sun Ultra 10 workstations and leased 56-kilobits-per-second (Kbps) data communication lines to publish and transmit various data objects such as Event objects and Vehicle Detector Station (VDS) objects. Each Event object is 2 kilobits (250 Bytes), and is transmitted when an event or incident has been confirmed, updated or terminated. If one Event object were posted per minute, the required bandwidth would be 0.03Kbps. Each VDS object is 16 bits (2 Bytes), and roughly 2000 VDS objects are transmitted every 30 seconds for a required bandwidth of 1.07Kbps. The total bandwidth required for exchanging data is, therefore: 0.03 + 1.07 = 1.1Kbps, which is well within the 56Kbps capacity limit. However, even if system usage threatened to exceed this limit, additional bandwidth could be leased or purchased from the telecommunications provider.

Software design also effects scalability. The more modular the software is, the easier it is to modify without making major design or architectural changes. IMAJINE's object-oriented software design is modular and utilizes Showcase's standardized, non-proprietary objects. Adding centers to the IMAJINE network should not require a change to the system architecture. Furthermore, since IMAJINE is a distributed system in which each workstation processes its own workload, adding centers to the network should not significantly impact the system's performance.

3.3 Impact of Showcase Integration on Project Deployment and System Performance

IMAJINE is one of 17 projects that make up the Showcase Program and Network. As such, many interdependencies developed between the projects as plans were made for eventual regional and corridor-wide integration. This section describes how these interdependencies impacted IMAJINE and other Showcase projects.

3.3.1 Impact of IMAJINE on other Showcase Projects

IMAJINE is the First Showcase Project to Integrate Traffic Operations, Transit Operations and Kernel Version 1.0

As the first Showcase project to involve a multimodal, interjurisdictional exchange of data, IMAJINE is Southern California's trailblazer for developing object definitions and interface standards for transit. These standards provide a common understanding of the representation and interaction of transit elements (e.g. buses, drivers, routes) in object-oriented software. When employed in subsequent transit-related ITS projects in Southern California, these standards will aid system integration, help ensure system interoperability, and support the Showcase Program's goal of "design once, deploy many times," which seeks to achieve cost efficiency through modular system design and software reuse.

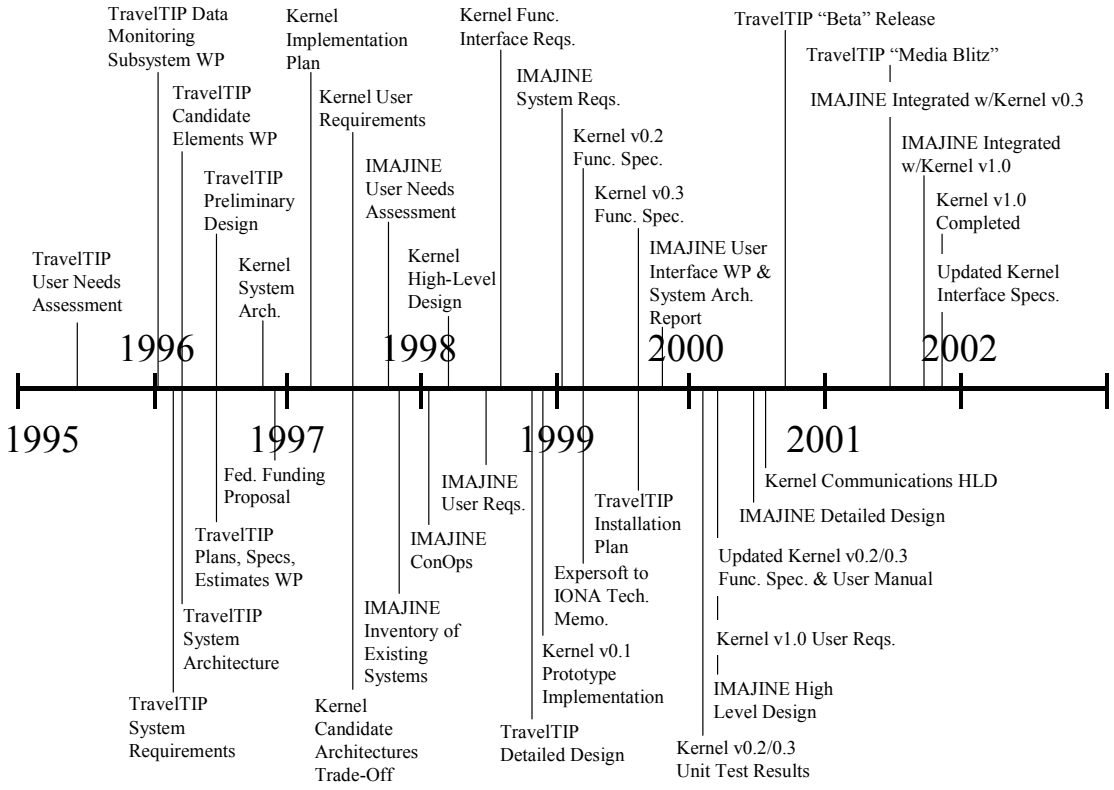
3.3.2 Impact of other Showcase Projects on IMAJINE

Delays with the Kernel Delayed the Development of IMAJINE

The four regional Kernels comprise the centerpiece of the Showcase Architecture. The Kernels authenticate (identify and approve) agency centers that wish to log on to the Showcase Network, as well as provide additional common services such as location translation, "yellow pages," publish & subscribe, and query. Regional systems that wish to exchange information across the interregional Showcase Network must contain software to communicate and interface with the Kernels.

As shown in Exhibit 9, the Kernels were developed in parallel with other Early Start projects such as IMAJINE and TravelTIP. This situation of concurrent development provided an opportunity for constructive feedback between the projects, but also slowed development of all three as design details were shared and consensus was built.

Exhibit 9 – Joint Timeline of the IMAJINE, TravelTIP and Kernel Early Start Projects



In an effort to conserve the project budget in the face of the slowed progress, the IMAJINE project team took a three-month "hiatus" during November 1998 – January 1999. Although the hiatus was helpful at the time, further delays in the development of the Kernel continued to impact IMAJINE throughout its completion.

4 Cost Evaluation

The cost evaluation draws information from documented costs and personal interviews. Budget information was taken directly from the project's contracts and amendments, while operations and maintenance costs were obtained from discussions with agency personnel. Informal interviews were conducted to verify information and fill in any "holes" that were discovered during analysis.

4.1 Constraints & Assumptions

There are two primary considerations for the Cost Evaluation:

- Since IMAJINE was funded through a firm fixed price contract, the project's budget information reflects the expenses and costs for services paid by the client agency, but not necessarily the actual detailed costs for goods and services comprising the project.
- Operations and maintenance (O&M) costs have been estimated based on available information and certain assumptions indicated later in this section.

4.2 Project Budget & Estimated Development Costs

This section addresses the project's contracted tasks and budget, as well as its role in supporting the Showcase Program's "design once, deploy many times" philosophy.

4.2.1 Project Budget

Although the project took longer than anticipated, it was completed within budget. Also, the budget was increased by 2.5% to cover additional work scope.

Roughly $3,075,000 was made available for the IMAJINE contract. Exhibit 10 lists the project's nine tasks and the budget associated with each one, as agreed to in the initial contract and subsequent contract amendments. More detail regarding each task is provided below. Since the project was negotiated as a fixed-price contract, the figures shown in Exhibit 10 reflect the expenditures by the client agency but not necessarily the actual costs for the services and equipment comprising the project.

IMAJINE's work scope originally only called for integration to Kernel version 0.3. The "final budget" in Exhibit 10 reflects an increase of 2.5% in order to cover the added task of integrating IMAJINE with the Kernel version 1.0.

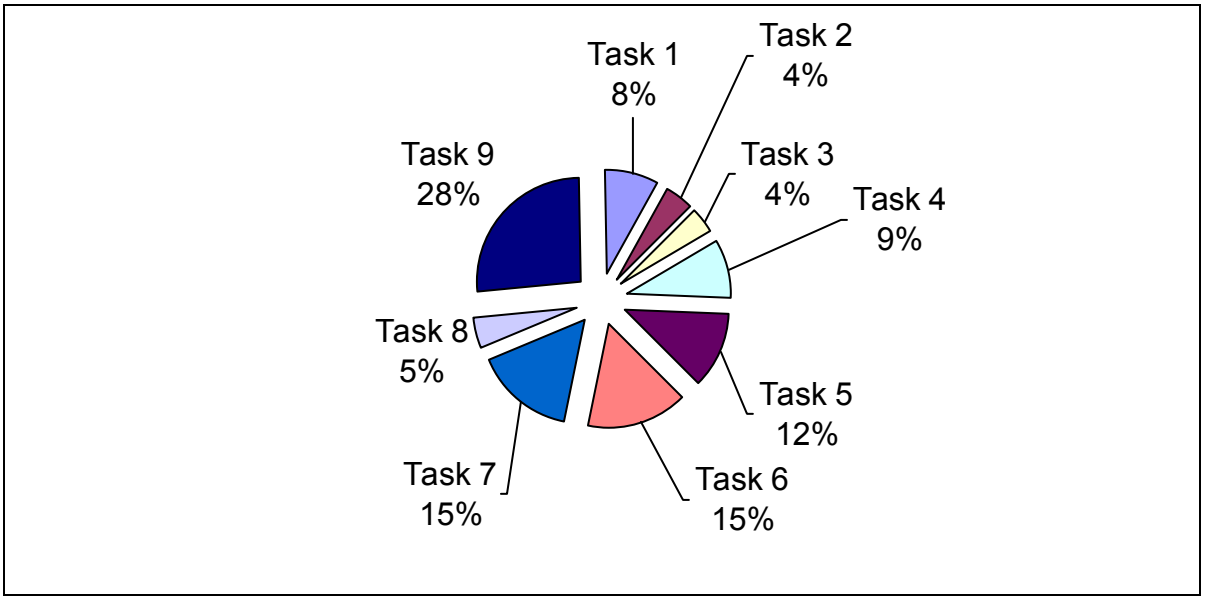
Exhibit 10 – IMAJINE Project Budget per Task[4]

Task/Cost Item	Initial Budget	Initial %	Final Budget	Final %
Task 1 – Project Management	$260,437	8.7%	$260,437	8.5%
Task 2 – Outreach	$130,220	4.3%	$130,220	4.2%
Task 3 – Needs Assessment	$133,225	4.4%	$133,225	4.3%
Task 4 – Requirements	$268,450	9.0%	$268,450	8.7%
Task 5 – High Level Design	$358,600	12.0%	$358,600	11.7%
Task 6 – Detailed Design	$436,735	14.6%	$468,630	15.3%
Task 7 - Implementation & Integration	$443,745	14.8%	$476,155	15.5%
Task 8 - Acceptance Testing	$142,235	4.7%	$152,631	5.0%
Task 9 – Equipment	$824,000	27.5%	$824,000	26.8%
Total	**$2,997,647**	**100.0%**	**$3,072,347**	**100.0%**

A quick look at Exhibit 10 and Exhibit 11 shows that the greatest single cost of IMAJINE consisted of equipment. Four workstations – which are responsible for interfacing with existing legacy systems and providing an operator interface – were purchased for the four project partner agencies. The estimated total cost for the four workstations (hardware only) is $30,836. The remainder (and majority) of the equipment cost was for network components and for upgrading existing systems at MTA and South Gate to make them compatible with current software standards and tools.

Implementation and Integration (which includes COTS software purchases and custom software development) accounts for about 15% of IMAJINE's total budget.

Exhibit 11 – Final Distribution of IMAJINE Budget by Task



The high-level system diagram in Exhibit 6 on page 16 shows that the IMAJINE system consists of the following hardware:

Exhibit 12 – IMAJINE System Hardware Items

Hardware Item	Quantity	Unit Cost❶	Total Cost
Sun Ultra 10 Workstation w/monitor at South Gate (includes video card)	1	$12,570	$12,570
Sun Ultra 5 Workstation w/monitor at ASI	1	$4,050	$4,050
Sun Ultra 10 Workstation w/monitor at MTA	1	$7,108	$7,108
Sun Ultra 10 Workstation w/monitor at Caltrans D7	1	$7,108	$7,108
Cisco 1605 Routers	3	$1,265	$3,795
Cisco 2524 Router	1	$1,777	$1,777
Interdyne Encoders	3	$7,759	$23,277
Interdyne Decoders	3	$5,170	$5,170
Cisco 802 ISDN Router (ASI)	1	$688	$688
Cisco 802 ISDN Router (MTA)	1	$688	$688
Cisco 802 ISDN Router (South Gate)	1	$688	$688
Cisco 802 ISDN Routers (Caltrans)	3	$688	$2,064

❶ Cost at time of purchase in 1999.

Based on this information, COTS hardware costs for the IMAJINE project totaled an estimated $68,983.

4.2.2 Design Once, Deploy Many Times

IMAJINE supports the "design once, deploy many times" philosophy through the use of the Showcase Program's high-level Kernel-Seed architecture, object-oriented technology, and standardized objects and interfaces.

"Design Once, Deploy Many Times" is the Priority Corridor's philosophy for achieving cost efficiency through a modular system design, software re-use, and "economy of scale." In general, IMAJINE supports the "design once, deploy many times" philosophy through the use of the Showcase Program's high-level Kernel-Seed architecture, object-oriented technology, and standardized objects and interfaces (CORBA IDL).

IMAJINE's design is based on the high-level Kernel-Seed architecture developed under the Scoping and Design project. This architecture specifies the use of standard objects and interfaces to help ensure system-to-system interoperability. Some of the object definitions used by IMAJINE, particularly the VDS object, were developed under the TravelTIP project and ported to IMAJINE. Similarly, several object definitions developed under IMAJINE were utilized in the Los Angeles/Ventura Regional ATIS project. These object definitions include the transit bus object, CCTV object, and CMS object.

4.3 Estimated Operations & Maintenance Costs

Because IMAJINE's O&M costs are funded by each respective partner agency, the project team designed the system with low operating costs in mind. This design feature is successfully demonstrated by an estimated annual O&M cost per agency of between $1932 and $2651.

4.3.1 Operations

The operations cost for IMAJINE has been broken down into three contributing components: labor costs, utility costs, and office space costs. Each of these cost components applies in a varying degree to each project participant. For example, not all agencies plan to continuously monitor their Remote Workstations or to hire technicians specifically for that purpose. An agency that wishes to estimate what its costs might be if it were to become an IMAJINE partner should review and add up the itemized costs that best apply to its planned mode of operation.

In the case of IMAJINE, each agency funds the operations and maintenance of its own system. This was a criterion for agency participation in the project.

4.3.1.1 Labor

The IMAJINE system provides a user interface for entering and viewing advisories about known incidents, scheduled maintenance, and other events that might impact traffic. While larger TMCs might find it necessary to assign one or more FTEs to monitor and enter advisories on the system, this is probably not warranted (and likely not cost-effective) for smaller TMCs.

The partner agencies report that they currently do not assign staff to operate the system and, therefore, do not incur a direct labor cost from IMAJINE. However, as noted in Section 3.2.1, the IMAJINE project is only one step of a multi-stage effort, and the system's capabilities are expected to expand with the future installation and integration of additional equipment. At that time, partner agencies may assign staff to operate the system, which may cause direct labor costs to be incurred.

4.3.1.2 Utilities

The utility costs that are most attributable to the IMAJINE system are electricity (for powering the Remote Workstations) and telecommunications (for interagency communications). Some partner agencies experience a greater cost impact than others, depending on the number of legacy systems already in place. Exhibit 13 estimates the annual electricity cost impact that could be produced by IMAJINE hardware. These estimates are based on the following assumptions:

- An average electricity rate of $0.16 per kW-hour (the actual rate varies seasonally)
- PCs and workstations operate 8 hours per day, 48 weeks per year
- Monitors draw 135W for 8 hours each day, draw 15W in "sleep" mode overnight, and operate 48 weeks per year.

Exhibit 13 – Estimated Marginal Annual Electricity Costs for IMAJINE

Hardware Item	Model	Power Draw	Power Cost	Est. Annual Cost
1 Remote Workstation	Sun Ultra 5	250W ea.	$0.16/kW-hr	$77
2 Remote Workstations	Sun Ultra 10	250W ea.	$0.16/kW-hr	$154
3 typical 21" color monitors	Various	15W-135W ea.	$0.16/kW-hr	$163
				$394

Because telecommunications make up the greatest portion of the monthly operating cost, IMAJINE uses separate services for its low-cost, low-bandwidth data needs and its high-cost, high-bandwidth video needs. As depicted previously in Exhibit 6, IMAJINE's telecommunications needs consist of the following:

Exhibit 14 – Monthly and Annual Telecommunications Costs (Data only)

Description	One-time Installation Fee	Ongoing Monthly Cost	Ongoing Annual Cost
Leased 56Kbps data connection from South Gate to Caltrans D7.	$1260	$149	**$1788**
Leased 56Kbps data connection from MTA to Caltrans D7.	$1260	$100	**$1200**
Leased 56Kbps data connection from ASI to Caltrans D7.	$1260	$100	**$1200**
			$4188

The monthly cost for the ISDN service at South Gate, MTA and ASI is based on actual number of hours of usage. For Exhibit 15, the estimated monthly cost for these agencies assumes a 22-working-day month with one hour of use per workday. Caltrans, however, pays a flat monthly rate that was previously negotiated by the State of California.

Exhibit 15 – Monthly and Annual Telecommunications Costs (Video only)

Description	One-time Installation Fee	Est. Ongoing Monthly Cost	Est. Ongoing Annual Cost
Leased 128Kbps ISDN video connection for South Gate.	$220	$61	**$732**
Leased 128Kbps ISDN video connection for MTA.	$220	$61	**$732**
Leased 128Kbps ISDN video connection for ASI.	$220	$61	**$732**
4 Leased 128Kbps ISDN video connections for Caltrans D7.	$880	$116	**$1392**
			$3588

Exhibit 16 combines the estimated annual costs for data and video telecommunications to arrive at an estimated total annual telecommunications cost per IMAJINE partner agency and overall.

Exhibit 16 – Summary of Estimated Annual IMAJINE Telecommunications Costs per Agency

Description	Data Connection	Video Connection	Est. Ongoing Annual Cost
South Gate	$1788	$732	**$2520**
MTA	$1200	$732	**$1932**
ASI	$1200	$732	**$1932**
Caltrans D7	$0	$1392	**$1392**
			$7776

Exhibit 17 combines the estimated annual costs for electricity (from Exhibit 13) and telecommunications (from Exhibit 16) to arrive at an estimated total annual utility cost per IMAJINE partner agency and overall.

Exhibit 17 – Total Annual Utility Costs per Agency for Operating IMAJINE

Agency	Electricity	Telecommunications	Total
ASI	$131	$1932	**$2063**
Caltrans D7	$0	$1392	**$1392**
MTA	$131	$1932	**$2063**
South Gate	$131	$2520	**$2651**
			$8169

4.3.1.3 Office Space

All partner agencies reported that there was no additional financial cost for the space occupied by IMAJINE equipment because there is no specific accounting down to the project or system level.

4.3.2 Maintenance

Each agency covers its own system maintenance costs, including both labor and replacement hardware/software. At this time, there is no data to support estimation of this cost.

5 Institutional Impacts Evaluation

5.1 Impacts to Operations and Maintenance Procedures and Policies

Each Partner Agency Pays its Own O&M Costs

As a policy, the MTA will not fund the O&M costs of other agencies. Participation in the IMAJINE project was contingent upon this condition. As a result, each agency agreed to program the necessary funding to cover O&M of its system.

5.2 Impacts to Staffing/Skill Levels and Training

IMAJINE has had no impact to staffing or required skill levels.

Users with general computer skills can operate an IMAJINE workstation. The workstations have an intuitive Windows™-like user interface, and NET provided training and demonstrations to familiarize the project partners with the system's full range of capabilities.

ASI manages a call center to take and process paratransit service requests. IMAJINE is just one more tool to which ASI operators have access for processing such requests and providing travel itineraries to their patrons. The rest of the IMAJINE system is automated and does not necessarily require human intervention. Transit route and schedule information is automatically extracted from the MTA's transit database for use by ASI. Incident information is automatically extracted from the Caltrans District 7 ATMS for use by South Gate's ICONS traffic control system.

Operator and System Administrator training was provided.

The System Developer provided training as part of the project to help familiarize agency operators/representatives with the system's user interface and features. To accommodate busy schedules, agency staff (operators) were invited to attend one of four 8-hour classes consisting of lecture and hands-on workstation training. In addition, system administration staff were also invited to one of two 8-hour System Administrator/Maintenance Training classes. Manuals were also provided for participants to keep.

5.3 Impacts to the Competitive Environment

IMAJINE's system design is documented and non-proprietary.

IMAJINE is the first Showcase project to successfully integrate to Kernel v1.0 using the Corridor's standard object definitions and CORBA IDL. Possession and understanding of the complete object definitions and IDL would be sufficient to enable the future implementation and addition of new centers to the Showcase Network. Many of these object definitions and IDL are contained in various design documents for IMAJINE and the Kernel, but no review has been done by the Priority Corridor to consolidate the information and verify its completeness.

5.4 Impacts to Local Planning Processes, Policy Development, and the Mainstreaming of ITS

IMAJINE helped create both a physical and institutional foundation for further ITS development in Los Angeles County.

Physically, one of the greatest accomplishments of the Showcase Program is its development of system interface standards for Southern California. Similar to the national effort on NTCIP, adoption of these standards will help promote interoperable systems that enable greater information sharing, improved agency coordination, and reduced costs over time. Furthermore, the deployment of the regional network and several new agency centers (Remote Workstations) provides a foundation on which functions and services can be tested, analyzed, improved, and added.

Perhaps more importantly, IMAJINE creates an institutional foundation that helps to mainstream ITS in the region. Through the IMAJINE experience, regional partners have had the opportunity to face and resolve critical institutional issues and establish precedents for the region's future ITS projects. Some of these critical issues include, but are not necessarily limited to:

- System and information security
- System reliability
- Policies regarding shared control of field equipment such as CCTVs and CMSs
- Software ownership and the treatment of intellectual property rights
- Delegation of operations and maintenance responsibilities (including funding).

These precedents should help clear the way for future ITS advancements in Los Angeles County.

6 Traveler and Transportation Information Management Evaluation

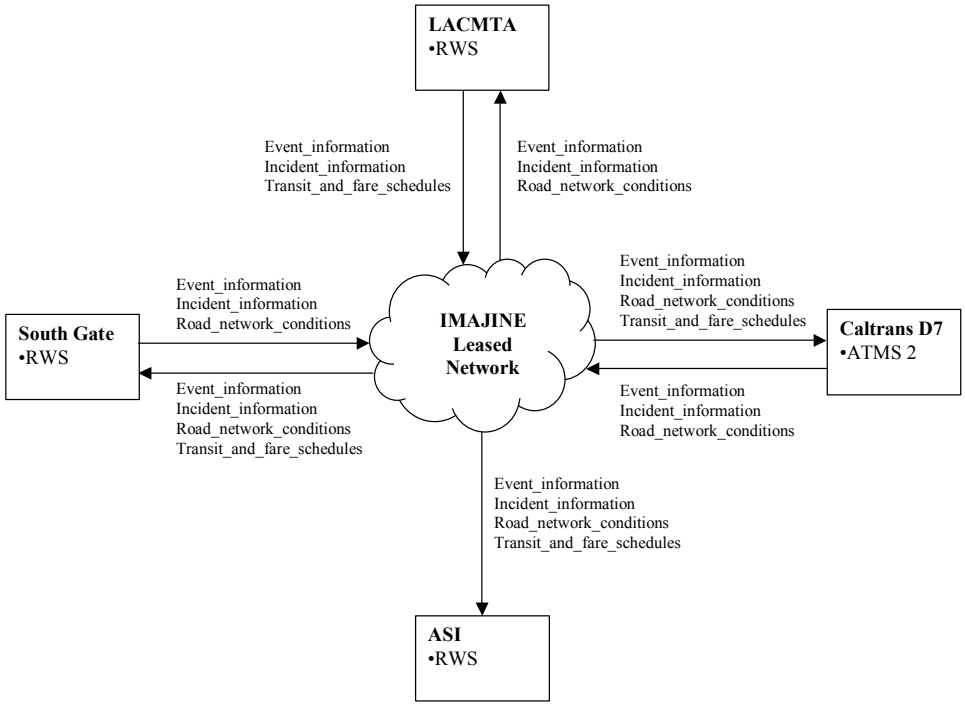
6.1 Extent of Regional and Interregional Transportation and Traveler Information Integration Between Agencies

6.1.1 IMAJINE System Impact on Data Flows

Prior to IMAJINE, there was no interagency integration of transportation management systems in Los Angeles County. IMAJINE lays the foundation for the expanded exchange and use of transportation data among the regional partners.

Exhibit 18 is a simple depiction of the ITS architecture flows implemented by IMAJINE (see definition of 'architecture flow' in the National ITS Architecture). *Road_network_conditions* consisting of a real-time color-coded traffic flow map, CCTV images, and current CMS messages are made available to the partner agencies. *Incident_information* provided by Caltrans District 7 is utilized by the City of South Gate to select and implement alternate traffic signal timing plans (primarily in response to freeway incidents and the resulting traffic diverting onto local arterials). Static *Transit_and_fare_schedules* from MTA are made available to the partner agencies, and primarily utilized by ASI to coordinate service and better advise patrons. The partner agencies (except ASI) also have the capability to manually enter and share textual *Event_information*.

Exhibit 18 – ITS Architecture Flows Implemented by IMAJINE



6.1.2 Operators Perceptions on Impact to Communications

ASI reports that its call center operators routinely use the MTA website, not IMAJINE, to obtain transit route and schedule information.

ASI has a staff of dedicated call center operators to handle requests from patrons seeking paratransit services. ASI was interviewed to determine its operators' perceptions of the impact of IMAJINE on their productivity. Although the IMAJINE system provides more up-to-date MTA transit bus and rail schedule information, ASI reports that its operators routinely use the MTA website to obtain the same information. ASI reports that the MTA website has been available much longer than IMAJINE and that the ASI operators have simply grown accustomed to using it. Another advantage of the website is that it is accessible from any computer that has access to the Internet, while IMAJINE is confined to its own unique workstations. Continued follow-up by MTA may be necessary to promote the IMAJINE system.

MTA Bus Operations wants an IMAJINE workstation because they anticipate real performance benefits.

MTA's IMAJINE workstation was installed in the Planning Department to demonstrate its capabilities. Now that MTA Bus Operations staff have had an opportunity to visit and view the workstation, they indicate that they want one of their own in order to obtain and use the Caltrans data that is provided by the system.

MTA's Bus Operations reports that this information could be used to detour buses around incidents and events (e.g., road maintenance, parades) to maintain timely service. This could also help stage buses to pick up passengers at stops downstream from the incident or event location. In the future, MTA Bus Operations would like to disseminate this incident and event information to passengers.

7 Transportation System Impacts Evaluation

This chapter describes the impacts of the IMAJINE system on the transportation network in Los Angeles County. Since IMAJINE is only the first step of a multi-stage program, and some of the functionality is pending the installation of additional equipment, a detailed impacts analysis is not possible. The following sections describe the current status of the IMAJINE system.

7.1 Impacts to Mode Shifting and Intermodalism

Once AVL has been added to MTA buses, IMAJINE's traffic signal priority feature will help improve transit speeds and on-time performance, which may encourage mode shifting. A more thorough impacts analysis might be warranted once the AVL is in place.

7.2 Impacts to Traffic Safety and Accident Reduction

Caltrans District 7 provides freeway incident data to South Gate through the IMAJINE system. Once incident response plans have been developed and installed, and the system is able to automatically adjust traffic signal timings, there may be a positive impact to traffic safety and accident reduction. A more thorough impacts analysis might be warranted once the response plans have been implemented.

7.3 Impacts to Traffic Congestion

As stated above under "*Impacts to Traffic Safety and Accident Reduction*," IMAJINE may have a positive impact on relieving traffic congestion once incident response plans have been developed and installed at South Gate.

7.4 Impacts to Environmental Effects of Traffic

Reducing traffic congestion may result in less overall fuel consumption and reduced vehicle emissions. A more thorough environmental impacts analysis might be warranted once IMAJINE is shown to reduce traffic congestion.

7.5 Impacts on Transit Operations

As stated under "Impacts to Mode Shifting and Intermodalism," IMAJINE's traffic signal priority feature will help improve transit speeds and on-time performance once the AVL system has been installed. A more thorough impacts analysis might be warranted once the AVL is in place.

8 Conclusions and Recommendations

IMAJINE brings the Los Angeles region one step closer to achieving its vision of integrated ITS by helping to lay both a physical and institutional foundation for further ITS development and expanded exchange and use of transportation information among the regional partners. IMAJINE is the first system to be fully compliant with the Priority Corridor's Showcase Architecture, and it is the first Showcase project to successfully integrate local transportation management centers with the interregional Showcase Network.

IMAJINE's goal was to build an architecture and capability to integrate and exchange real-time transportation information. This capability has been successfully provided and proven through sample data transfers between systems at MTA, Caltrans District 7, South Gate and ASI. However, IMAJINE is only the first step of a multi-stage regional effort, and the transportation system impacts of the system are expected to become much greater as additional equipment is installed. IMAJINE's functionality will be enhanced by the procurement, installation and integration of additional equipment such as transit bus AVL and alternative traffic signal timing plans. The MTA is currently seeking funding to procure the transit AVL system, and development of the alternative traffic signal timing plans is planned as part of the currently ongoing I-105 Corridor/Gateway Cities project.

The fixed-price IMAJINE contract initially specified an 18-month period of performance due to FHWA requirements, but various factors contributed to exceeding this schedule:

- IMAJINE was developed concurrently and interdependently with two other projects: Showcase's Scoping & Design project (which developed the Showcase Kernel and critical interface standards for the entire Priority Corridor), and LACDPW's I-105 Corridor/Gateway Cities Subregional TMC project. Delays with both of these projects impacted IMAJINE.

- Consensus building takes time. Although IMAJINE's software implementation, integration and testing was able to be done in about 18 months, the coordination, consensus building and system planning that preceded these activities required nearly three years of effort. Although IMAJINE provides a data exchange capability between four agencies, additional stakeholder agencies involved in the planning process included FHWA, SCAG, LACDPW, Caltrans Division of New Technology & Research (now the Division of Research & Innovation), and the City of Los Angeles. This planning and consensus building took place in steps as project deliverables were released to the stakeholder group.

  The two deliverables that required the most time were the User Requirements and Systems Requirements documents. Each of these documents required about six months of consensus building, preparation, review, discussion, and revision to complete. Future ITS projects might benefit from the following observations regarding system planning and document development:

  1. Approach the system development in "baby steps." Keep the first implementation as simple as possible by focusing on only the most basic and critical system requirements,

and leave less critical items to future builds of the system. During the IMAJINE project, workshops were held to capture stakeholders' desires for the system. All of these desires were catalogued in the project's Requirements document, but an additional Implementation Phasing Plan (IPP) was developed to specify which requirements would be implemented immediately and which ones would be saved for future builds. This approach encouraged stakeholders to be open and creative, provided an archive for the ideas generated, but also provided a mechanism for managing what could be reasonably accomplished within the existing project budget.

2. Develop and use formal document review procedures that define the manner and format in which comments/issues will be received, processed, and resolved. With so many stakeholders involved in the IMAJINE project, this helped streamline the task considerably.

3. If schedule adherence is a top priority for the project, strictly limit the amount of time to read and review a document to two weeks, and gain stakeholder commitment to maintain this schedule. Although this will help keep the project on schedule, it may conflict with stakeholders' busy schedules and hinder or sacrifice their involvement. The IMAJINE project team considered stakeholder involvement to be a higher priority, so document reviews were sometimes extended to several months.

4. Make formal oral presentations of major documents to stakeholders in order to gather direct feedback and respond more quickly to stakeholder concerns. This is particularly useful for large, detailed documents that would otherwise require a more careful and lengthy review. This approach provides an opportunity to discuss any overly detailed information, as well as helps summarize and bring focus to the more important items that may require timely stakeholder action. The project team used this approach to present the system's Detailed Design document.

5. Dictate drafts of major documents onto tape or CD and circulate them as "books-on-tape" so that they are more convenient to carry and review while traveling, commuting, etc. This may be useful for those who are looking for ways to more efficiently use their time. Although this approach was not employed during the IMAJINE project, the evaluation provides it as a novel approach for others to consider.

Regardless of the extra time required to complete the IMAJINE project, the project was completed within its initial budget. This adherence to the original budget is due in part to cost-mitigating actions, such as occasional work stoppages, taken by the project team. Future ITS projects might benefit from a phased or task order approach that permits a re-evaluation of the project's progress and costs after each systems engineering step. This approach would aid in estimating project cost and duration, and would relieve some of the financial risk imposed on contractors by fixed-price agreements.

Since operations and maintenance of the system is funded by each respective partner agency, low O&M costs were an important design consideration. This requirement has been met with an

estimated annual O&M cost per agency, including power and telecommunications services, of between $1932 and $2651 (or about $200 per month). Since agency staff resources are often limited, much of the IMAJINE system is designed to operate autonomously, thus avoiding additional labor costs.

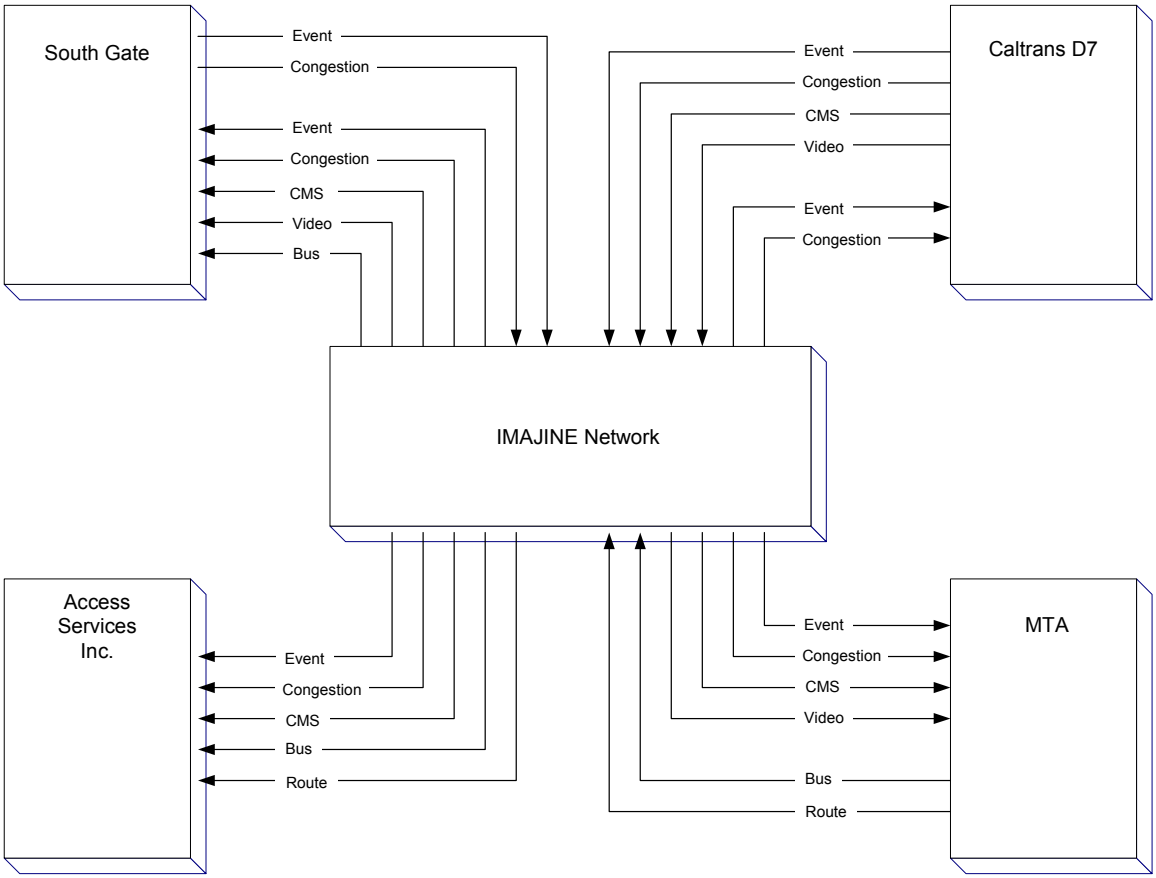
Appendix A – The IMAJINE Object Model

IMAJINE enables the exchange of various transportation data between partner agencies for the benefit of improvements in communication, coordination and efficiency. The IMAJINE software that enables this exchange is based on an object-oriented design that involves six types of information. These six types of information include:

- Bus – relates to individual transit buses
- CMS – relates to Changeable Message Signs
- Congestion – relates to roadway traffic volumes, lane occupancies and speeds
- Event – relates to incidents as well as planned lane closures or service disruptions
- Route – relates to transit routes
- Video – relates to images or feeds from CCTV surveillance cameras

The exhibit below depicts the four IMAJINE project partners and the data exchanged between them. Some details about how the object-oriented software is used to pass this information follow the exhibit.

Exhibit A1 – IMAJINE Data Exchanges



Bus information

Bus information is passed through the Bus object, which consists of one "attribute," *scheduleOffset*, which indicates the number of minutes the bus is either ahead of schedule or running behind. In addition, the Bus object provides four "methods" for retrieving or determining a bus' current route, current trip, last stop, and time of last information update.

Bus
-scheduleOffset
+currentRoute() +currentTrip() +lastStop() +timeOfLastUpdate()

CMS information

CMS information is passed through a CMS object. Each CMS object contains information regarding a changeable message sign. The object's attributes describe the sign's display format (ASCII, graphic, etc.), operational status (blank, failed, etc.), communications protocol (HP, SignView, etc.), maximum number of display phases, and any data needed for displaying a queued message. The object's methods can reset the sign, set the message flash rate, add a message to the sign's message queue, remove a message from the message queue, change a message's priority or order in the sign's message queue, and set or change the date and time that a message should be turned on or off.

CMS
-cmsType -state -protocol -maxPhases -msgQueue
+reset() +flash() +addLibMessage() +removeMessage() +changePriority() +activateAt()

Event information

Roadway event information is passed through a collection of Event objects. The Event object provides basic information regarding incidents such as accidents or debris in the roadway, as well as planned lane closures for road maintenance or special events. More specialized *Advisory*, *Incident*, *Special Event*, *Planned Lane Closure*, and *Emergency Closure* objects contain all of the attributes and methods below, plus additional information and functionality specific to those event types.

Event
+eventID -eventLocation -drawAttributes -state -eventAlarm -detectingAgency -reportingAgency -log -trafficImpact +priority +prioritizer -advisoryText -actualStart -responseStart -clear -relax -actualEnd -duration -lastUpdate
+respond() +confirm() +store() +terminate() +updateLog() +updateLocation() +getDescription() +description() +getResponseObjSet() +activeResponsePlan() +proposedResponsePlan() +promoteResponsePlan() +terminateResponsePlan() +getLaneSet() +addLane() +modifyLane() +removeLane() +getLinksSet() +addLink() +removeLink() +lock() +unlock()

Congestion information

Quantitative highway and arterial traffic congestion information is contained and exchanged through the Segment object, which represents traffic conditions along a section of roadway that usually includes several sensors. The Segment object describes the location and geometry of the roadway segment for graphical display, as well as the average speed and travel time as determined from available field detectors and the length of the segment.

Segment
-segmentLocation -aveSpeed -aveTravelTime -vdsList -segmentId -segmentLength -segmentPoints -vdsRefs
+nominalSpeed()

Transit Route information

The Route object supplies the information necessary to fully describe a transit bus route consisting of stops and trips. Route trips are defined as scheduled stops that a transit bus must make for a given time of day. A single route can, and usually does, consist of several trips. Stops can be time points, transfer points, or minor stops.

Route
-id -name -descript_1 -descript_2 -rteDirections -rteServices -state -stops -trips
+allStopsForDirection() +stopCountForDirection() +stopCount() +stopIterator() +stopById() +stopByName() +specificTrip() +tripsForDirectionAndService()

Video information

The CCTV object provides the interface to access and control video cameras in the field. The CCTV object contains a "protocol" attribute, and several methods for determining and adjusting camera position and focus.

Video
-protocol
+unlock() +lock() +queryLock() +videoConnect() +videoDisconnect() +titleEnable() +titleDisable() +videoOutputList() +panLeft() +panRight() +panStop() +tiltUp() +tiltDown() +tiltStop() +zoomIn() +zoomOut() +zoomStop() +focusNear() +focusFar() +focusStop() +irisOpen() +irisClose() +irisStop() +irisAuto() +irisManual() +queryIris() +presetFirstId() +presetLastId() +presetList() +savePreset() +goPreset() +queryPreset() +overlayLineLimit() +overlayCharsPerLineLimit() +showOverlay() +hideOverlay() +overlayLines() +overlayLine() +queryOverlayDisplay() +powerOn() +powerOff() +queryPower() +queryPressure() +queryVideo() +positionGoto() +queryPosition() +lensGoto() +queryLens()

Endnotes/References

[1] ISTEA requires that "operational tests utilizing federal funds have a written evaluation of the Intelligent Vehicle Highway Systems technologies investigated and the results of the investigation." Although Showcase is not officially an operational test, it deploys and demonstrates ITS services, functions, and technologies under "real world" conditions, similar to an operational test.

[2] California Statistical Abstract, Table B-4. California Department of Finance, Sacramento, CA. October 2001.

[3] California Statistical Abstract, Table J-4. California Department of Finance, Sacramento, CA. October 2001.

[4] The total project budget numbers are accurate and come from the project contract (LACMTA PS-4340-0143) and its amendments. Individual task budgets were estimated based on approximations provided by NET.